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(54) Homopolymerization of acrylate or methacrylate endblocked polydiorganosiloxanes

(57) Method for homopolymerization of polyorganosiloxane macromonomers having acryloxy or methacryloxy groups. A miniemulsion of a methacryloxy functional polydimethylsiloxane macromonomer is prepared herein by mixing the macromonomer with a surfactant(s) and then subjecting it to a high shear device. The macromonomer is polymerized in the miniemulsion by using a free radical initiator at high temperature. The amount of unreacted macromonomer is very low.

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Description

This invention is directed to miniemulsion polymerization of acryloxypropyl and methacryloxypropyl functional polydiorganosiloxane macromonomers.

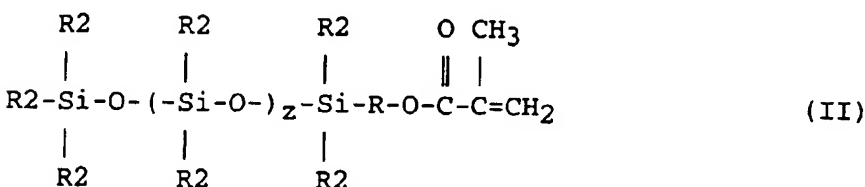
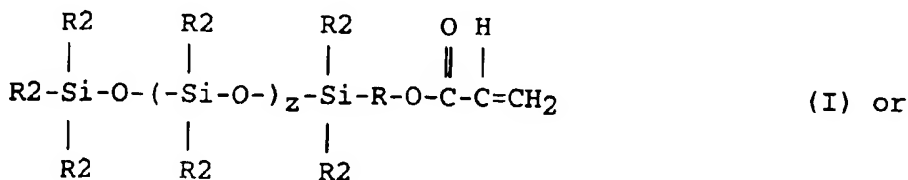
Emulsion polymerization is an important industrial method, because it produces high molecular weight polymers and because there is no or negligible content of volatile organic compounds (VOC). In a normal emulsion polymerization technique, the oil is emulsified in water with a conventional surfactant using a mechanical shearing device, to produce droplets of 1,000-10,000 nm in diameter. The polymerization is achieved with the assistance of a water or oil soluble initiator or catalyst. These emulsions are generally opaque, milky and viscous; but they can also be translucent emulsions with particle sizes ranging from 8-80 nm, when a very high surfactant concentration is employed.

In conventional emulsion polymerization, the micelles are the primary site for polymerization. However, El-Aasser et al in the Journal of Applied Polymer Science, Volume 43, Pages 1059-1066, (1991), show that nucleation can also occur in monomer droplets if they are very small. They termed this phenomenon as "miniemulsion polymerization", with particle sizes ranging from 50-500 nm. According to El-Aasser et al, the miniemulsions are more stable compared to conventional emulsions; they have small particle size, i.e., 50-500 nm. High shear devices such as a submicron disperser, a MICROFLUIDIZER® or an ultrasonication unit are used to make the miniemulsion.

According to their technique, a cosurfactant is employed, which is typically a low molecular weight, water insoluble compound, such as cetyl alcohol or hexadecane. It is used for the purpose of retarding the diffusion of the monomer out of the droplets. They postulate that the stability of such a cetyl alcohol system is attributed to the formation of intermolecular complexes at the oil/water interface, resulting in lower interfacial tension.

El-Aasser et al do not describe the homopolymerization of polyorganosiloxane macromonomers. We are not aware of any published report on the homopolymerization of acryloxy or methacryloxy functional polyorganosiloxanes in solution. Where there is reference to polymerization of silicone macromonomers, the reference is focused toward copolymerization of silicone macromonomers with conventional low molecular weight monomers and only low conversions have been observed, i.e., T. Chou et al, Polymer Processing, Volume 44[11], Pages 490-496, (1995).

Our invention provides a method of making an emulsion containing a homopolymer of a polydiorganosiloxane having acryloxy or methacryloxy groups. According to our method, we heat and shear a reaction mixture formed by combining (i) water; (ii) an anionic surfactant, a cationic surfactant, a nonionic surfactant, or a combination of such surfactants; (iii) a cosurfactant such as a fatty alcohol, n-alkane, or halogen substituted n-alkanes; (iv) a mono-acryloxyalkyl terminated polydiorganosiloxane macromonomer (I) or a mono-methacryloxyalkyl terminated polydiorganosiloxane macromonomer (II) having the formula

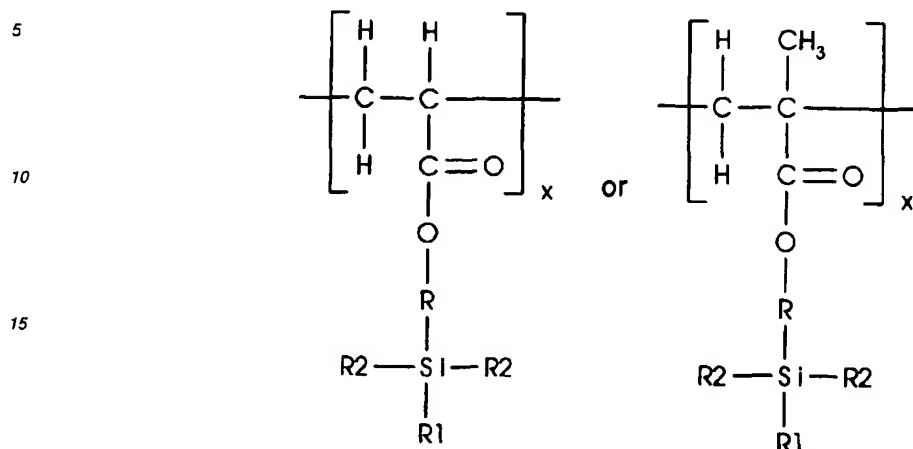


where R in each formula is a divalent hydrocarbon radical with 1-6 carbon atoms; R2 in each formula is a hydrogen atom, a C₁₋₈ alkyl radical, a haloalkyl radical, or an aryl radical; and z in each formula is 1-1,000; and (v) a free radical initiator.

Our invention also relates to the homopolymer made by our method and to an emulsion containing the homopolymer.

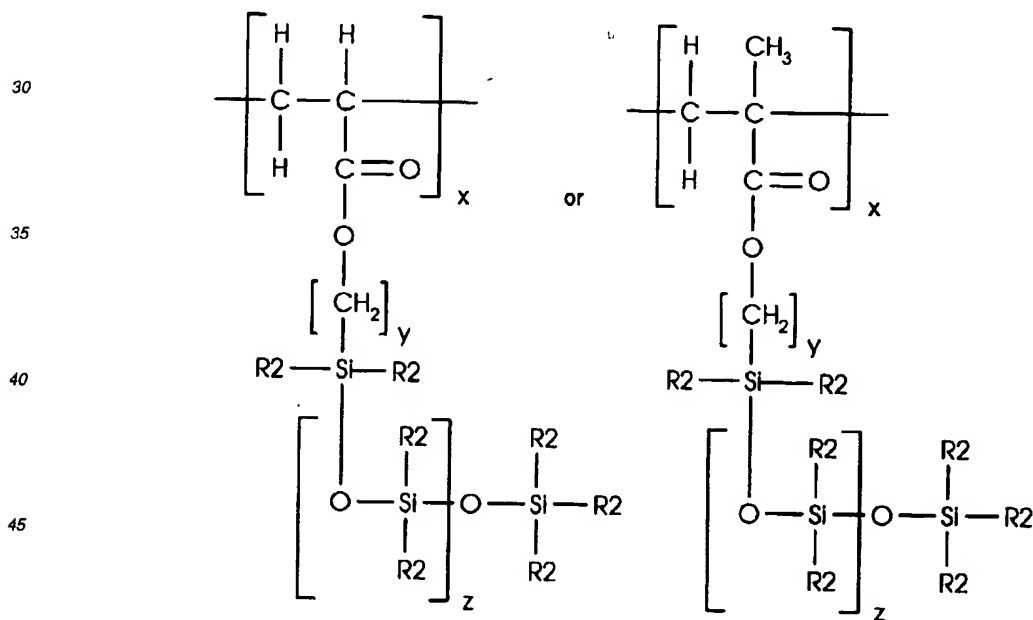
A macromer is a polymer of molecular weight ranging from several hundred to tens of thousands, having a functional group at the chain end that will further polymerize. The term macromer is an abbreviation of macromolecular monomer and macromonomer. While the functional group may be any polymerizable group, most typically it is vinyl, epoxy, dicarboxylic acid, diol, diamine, acryloyl or a methacryloyl.

The homopolymer prepared from the macromonomer (MM) by our invention is represented by either of the following formulas



where R₁ in each formula is a polyorganosiloxane moiety $-(\text{OSiR}_2)_2\text{OSiR}_2$; R₂ in each formula is a hydrogen atom, a C₁₋₈ alkyl radical, a haloalkyl radical, or an aryl radical; R in each formula is a divalent hydrocarbon radical with 1-6 carbon atoms; x in each formula is 2-5000; and z in each formula is 1-1,000.

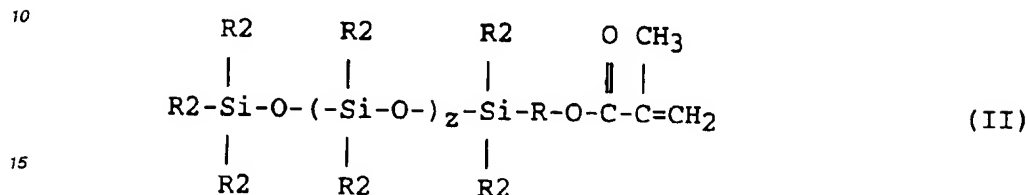
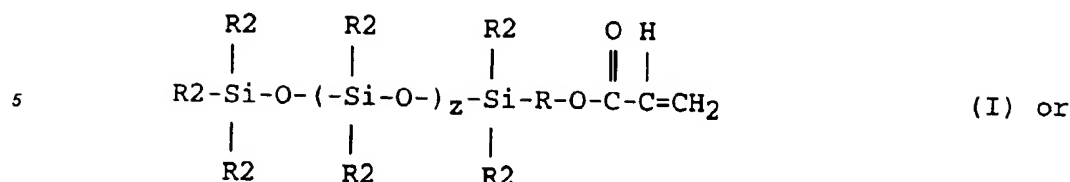
These homopolymers are shown in more detail below



where R₂ in each formula is a hydrogen atom, a C₁₋₈ alkyl radical, a haloalkyl radical, or an aryl radical; x in each formula is 2-5000; y in each formula is 1-6; and z in each formula is 1-1,000.

Some radicals representative of R₂ are alkyl radicals such as methyl, ethyl, isopropyl, butyl, pentyl, hexyl, heptyl and octyl; aryl radicals such as phenyl or xenyl; and haloalkyl radicals such as 3-chloropropyl, 4-bromobutyl and 3,3,3-trifluoropropyl.

The macromonomer (MM) used to prepare these homopolymers is either a mono-acryloxypropyl terminated polyorganosiloxane (I) or a mono-methacryloxypropyl terminated polyorganosiloxane (II) as shown below:



where R, R2 and z are as defined above. These macromonomers are prepared by methods known in the art, i.e., reacting a silanol endblocked polydimethylsiloxane with acryloxypropyl dimethylchlorosilane or methacryloxypropyl dimethylchlorosilane, in the presence of dibutylamine, for example.

The free radical initiator is an azo initiator conforming generally to the formula:



where R is an alkyl radical and Q is a simple carboxylic acid residue or a derivative thereof such as a nitrile ester.

The most preferred free radical initiator is the dialkyl diazine 2,2'-azobisisobutyronitrile (AIBN) shown below:



Similar initiating properties are obtained using 4,4'-azo-4-cyanopentanoic acid (ACPA), a compound shown in the previous formula where R is -CH₃ and Q is -(CH₂)₂COOH. ACPA is soluble in water, unlike AIBN.

Other classes of useful free radical initiators include dialkyl hyponitrites, diaroyl peroxides, dialkyl peroxydicarbonates, dialkyl peroxalates, dialkyl peroxides, alkyl hydroperoxides and disulfides.

The reaction medium contains ionic, nonionic and mixtures of ionic and nonionic surfactants to stabilize the polysiloxane in the emulsion. Ionic surfactants can be cationic or anionic including surfactants known in the art as useful in emulsion polymerization.

Suitable anionic surfactants include sulfonic acids and their salt derivatives. Useful anionic surfactants are alkali metal sulfosuccinates; sulfonated glyceryl esters of fatty acids, such as sulfonated monoglycerides of coconut oil acids; salts of sulfonated monovalent alcohol esters, such as sodium oleyl isothionate; amides of amino sulfonic acids, such as the sodium salt of oleyl methyl taurate; sulfonated products of fatty acid nitriles, such as palmitonitrile sulfonate; sulfonated aromatic hydrocarbons, such as sodium alpha-naphthalene monosulfonate; condensation products of naphthalene sulfonic acids with formaldehyde; sodium octahydro anthracene sulfonate; alkali metal alkyl sulfates; ether sulfates having alkyl groups of eight or more carbon atoms; and alkylaryl sulfonates having one or more alkyl groups of eight or

more carbon atoms. Commercial anionic surfactants useful in our invention include dodecylbenzene sulfonic acid (DBSA) sold under the name BIOSOFT™ S-100 by Stepan Company, Northfield, Illinois; and the sodium salt of dodecylbenzene sulfonic acid sold under the name SIPONATE™ DS-10 by Alcolac Inc., Baltimore, Maryland.

Useful cationic surfactants are the various fatty acid amines, amides and derivatives and salts of fatty acid amines and amides. Cationic surfactants are exemplified by aliphatic fatty amines and derivatives, such as dodecyl amine acetate, octadecyl amine acetate and acetates of amines of tallow fatty acids; homologues of aromatic amines having fatty chains, such as dodecyl aniline; fatty amides derived from aliphatic diamines, such as undecyl imidazoline; fatty amides derived from di-substituted amines, such as oleylamino diethylamine; derivatives of ethylene diamine; quaternary ammonium compounds, such as tallow trimethylammonium chloride, dioctadecyldimethyl ammonium chloride, didodecyldimethyl ammonium chloride and dihexadecyldimethyl ammonium chloride; amide derivatives of amino alcohols, such as beta-hydroxyethyl stearyl amide; amine salts of long chain fatty acids; quaternary ammonium bases derived from fatty amides of di-substituted diamines, such as oleylbenzylamino ethylene diethylamine hydrochloride; quaternary ammonium bases of benzimidazolines, such as methylheptadecyl benzimidazole hydrobromide; basic compounds of pyridinium and derivatives, such as cetylpyridinium chloride; sulfonium compounds, such as octadecyl sulfonium methyl sulfate; quaternary ammonium compounds of betaine, such as betaine compounds of diethylamino acetic acid and octadecylchloromethyl ether; urethanes of ethylene diamine, such as condensation products of stearic acid and diethylene triamine; polyethylene diamines and polypropanol polyethanol amines. Commercial cationic surfactants include products sold under the names ARQUAD™ T-27W, 16-29, C-33, T-50; and ETHOQUAD™ T/13 and T/13 ACETATE by Akzo Chemicals Inc., Chicago, Illinois. The anionic or cationic surfactant is present at 0.05-30% by weight of the total emulsion and preferably 0.5-20%.

Useful nonionic surfactants have a hydrophilic-lipophilic balance (HLB) of 10-20. Nonionic surfactants with HLB of less than 10 may be used but hazy solutions may result due to limited solubility of the nonionic surfactant in water. When using a nonionic surfactant with HLB less than 10, a nonionic surfactant with HLB greater than 10 should be added during or after polymerization. Commercial nonionic surfactants are exemplified by 2,6,8-trimethyl-4-nonyloxy polyethylene oxyethanols (6EO) and (10EO) sold under the names TERGITOL® TMN-6 and TERGITOL® TMN-10; alkyleneoxy polyethylene oxyethanol (C₁₁₋₁₅ secondary alcohol ethoxylates 7EO, 9EO and 15EO) sold under the names TERGITOL® 15-S-7, TERGITOL® 15-S-9, TERGITOL® 15-S-15; other C₁₁₋₁₅ secondary alcohol ethoxylates sold under the names TERGITOL® 15-S-12, 15-S-20, 15-S-30, 15-S-40; and octylphenoxy polyethoxy ethanol (40EO) sold under the name TRITON® X-405. All of these surfactants are sold by Union Carbide Corporation, Danbury, Connecticut. Other commercial nonionic surfactants are nonylphenoxy polyethoxy ethanol (10EO) sold under the name MAKON™ 10 by Stepan Company, Northfield, Illinois. One especially useful nonionic surfactant is polyoxyethylene 23 lauryl ether (Laureth-23) sold commercially under the name BRIJ™ 35 by ICI Surfactants, Wilmington, Delaware.

Some commercially available ionic surfactants have characteristics of both ionic and nonionic surfactants combined, such as methyl polyoxyethylene (15) octadecyl ammonium chloride sold under the name ETHOQUAD™ 18/25 by Akzo Chemicals Inc., Chicago, Illinois. It is a cationic quaternary ammonium salt with polyethylene oxide tails. When this type of ionic surfactant is used, it may not be necessary to have both ionic and nonionic surfactants in the reaction medium. Only the ionic surfactant having the nonionic characteristics is needed. Surfactants such as ETHOQUAD™ 18/25 are typically used in our emulsion at levels equal to the level of ionic surfactants used.

A cosurfactant is used in the method according to our invention. The cosurfactant is preferably a hydrophobic solvent or a compound having low water solubility. Representative cosurfactants are, for example, fatty alcohols such as cetyl alcohol C₁₆H₃₃OH; and n-alkanes such as n-hexadecane (cetane) C₁₆H₃₄ or the halogen substituted derivatives thereof, such as 1-chlorodecane (decyl chloride) CH₃(CH₂)₉Cl. The presence of such a low molecular weight and relatively water-insoluble compound retards diffusion of monomer out of the droplets.

The reaction mixture is formed by combining 50-80 percent by weight of water; 5-15 percent by weight of the surfactant; 1-5 percent by weight of the co-surfactant; 10-50 percent by weight of the macromonomer; and 0.5-15 percent by weight of the free radical initiator. It is not essential that these ingredients be combined in any given order, although one preferred procedure is to combine water, surfactant(s) and cosurfactant(s), followed by addition of monomer and initiator. However, it is essential to have agitation during and following addition of the ingredients and to have achieved or to heat to the polymerization temperature as the ingredients are combined. Where practical, agitation and heating should be continued until the monomer is consumed in forming the emulsion.

The process we used for making miniemulsions is similar to the El-Aasser et al procedure; although our initiator was not the same as the initiator used by El-Aasser et al.

According to our process, sodium lauryl sulfate, cetyl alcohol and water, were first heated at 65°C. for 2 hours, cooled to 40-45°C. and passed through a high shear device to break the gel which formed. The high shear device was a high pressure impingement emulsifier, sold under the name MICROFLUIDIZER® by Microfluidics Corporation, Newton, Massachusetts.

Such high shear devices are described in detail, for example, in US Patent 4,533,254. In general, these high shear devices include a high pressure pump (i.e., up to about 25,000 psi/172,370 kPa) and an interaction chamber where

emulsification occurs. A reaction mixture is passed through the emulsifier once at a pressure between 5,000-15,000 psi/34,474-103,422 kPa. Multiple passes through the high shear device result in a smaller average particle size and a narrower range for the particle size distribution.

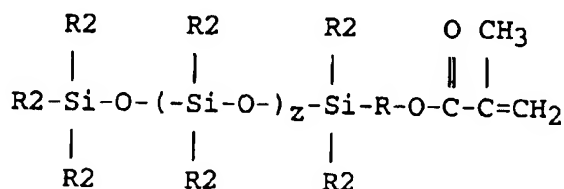
The macromonomer (MM) and the AIBN initiator are then added to the surfactant mixture and stirred at ambient temperature (20-25°C./68-77°C.). The mixture is again introduced to the MICROFLUIDIZER® and passed 4-5 times at 14,000 psi/96,527 kPa. Particle size was measured with the aid of a NICOMP™ particle size analyzer in dilute solutions. The emulsion was transferred to a 3-neck flask and after bubbling nitrogen, the emulsion was heated at 60-65°C. for a period of time.

After polymerization was complete, the emulsion was broken by adding sodium chloride and methanol. The precipitate was washed with hot water and dried in a vacuum. Molecular weights of the products were determined by Gel Permeation Chromatography (GPC) in toluene against polystyrene standards with a Refractive Index (RI) detector, or in chloroform against polyglycol standards with an IR detector. The frequency of the IR detector was fixed on Si-O stretching vibrations. The same methodology was applied in all examples shown below with little variation. The methacryloxypropyl polydimethylsiloxane macromonomer was further analyzed and characterized by GPC, IR, ¹³C and ²⁹Si Nuclear Magnetic Resonance (NMR). The GPC trace data and the IR spectrum data are shown in Table I. In the IR, the band at ~1640 cm⁻¹ was assigned to the double bond and the band at ~1726 cm⁻¹ was assigned to C=O vibrations.

Our invention is illustrated in more detail in the following examples. All reactions were carried out in an atmosphere of nitrogen. GPC analyses were performed on a WATERS™ 150C Chromatograph, using a flow rate of 1.2 ml/minute and an injection volume of 200 µl, in toluene against polystyrene standards and in CHCl₃ against polyglycol standards. A refractive index detector was used for toluene measurements and an IR detector with fixed wavelength on Si-O frequency was used for CHCl₃ measurements.

IR spectra were measured on neat liquids in KBr plates on a Perkin Elmer™ Spectrophotometer. Particle size measurements were made with a NICOMP™ 370 particle size analyzer. Thermogravimetric analysis (TGA) measurements were performed on a GENERAL V4.1C DuPont™ 2100 analyzer. Weighed samples were placed in a platinum pan and heated at 10°C./minute to 800°C. under a helium atmosphere. Surface tension measurements were carried out on a ROSANO™ Tensiometer with a platinum blade. Three measurements were taken on each sample and the values were averaged. Viscosity data were obtained on a BROOKFIELD™ DV-II Viscometer at 22.8°C.

The starting material used in these examples was the mono-methacryloxypropyl terminated polydimethylsiloxane macromonomer (MM) shown below:



where R2 is methyl, R is -CH₂CH₂CH₂- and z has a value sufficient to provide the (MM) with the viscosity at 23°C. shown in Table 2.

Example 1

Deionized water (69.02 gm) was placed in a 250 ml beaker equipped with a magnetic stirrer. Sodium lauryl sulfate (0.3 gm), an anionic surfactant and cetyl alcohol (0.6 gm) were added to the water and the contents were heated to 60-67°C. for 2 hours. The contents were allowed to cool to 40-45°C. and a white gel was obtained. The gel was introduced to a MICROFLUIDIZER® and the contents were stirred at least 5 times at 10,000 psi/68,948 kPa. The contents were removed from the MICROFLUIDIZER®, macromonomer MM (30 gm) was added to the contents and the contents were again stirred for 10 minutes with a magnetic stirrer. The mixture was next introduced to the MICROFLUIDIZER® and cycled at least 25 times at 14,000 psi/96,527 kPa. The average particle size was determined to be 289 nm. At this point, 2,2'-azobisisobutyronitrile (AIBN) (0.22 gm) was added and the emulsion was transferred to a 3-neck flask fitted with a nitrogen inlet, condenser and thermometer. The emulsion was heated at 65°C. for 65 hours. The heating was stopped and 10 gm of emulsion was set aside. The rest of the emulsion was broken by pouring it into methanol (500 gm) and a solution of NaCl in water (2 gm in 25 ml). The mixture was shaken vigorously. An off-white, sticky, polymer was obtained which was dried under vacuum. The yield was 20 gm.

In Example 1, the free radical azo initiator AIBN was added after the emulsion was prepared. The polymerization

was continued for 65 hours. The long reaction time was needed because higher molecular weight products were not observed in GPC analysis when the emulsions were heated 2-8 hours. After breaking the emulsion, the polymer was analyzed by GPC. The Mn, Mw and Mw/Mn values in toluene and chloroform are reported in Table 1.

As seen from the GPC data, 71% of the macromonomer was converted to the high molecular weight polymer, although the exact ratio of unreacted macromonomer and homopolymer may vary, as the response factor for the detector was not calculated. The polymer was not high in molecular weight. The number average molecular weight (Mn) value suggests that 10-11 of the macromonomer units were involved. The IR spectrum of the mixture (not shown) did not show any absorption at $\sim 1640\text{ cm}^{-1}$.

Surface tension and viscosity of the starting macromonomer and the polymerization products were measured and the data are given in Table 2.

Example 2

Deionized water (69.02 gm) was placed in a 250 ml beaker equipped with a magnetic stirrer. Sodium laurel sulfate (0.2 gm), dioctyl sulfosuccinate sodium salt (0.2 gm) and cetyl alcohol (0.7 gm) were added to the water and the contents were heated to 65-67°C. for 2 hours. The contents were allowed to cool to 40-45°C. and a white gel was obtained. The gel was introduced to a MICROFLUIDIZER® and the contents were circulated at least 5 times at 10,000 psi/68,948 kPa. The contents were removed from the MICROFLUIDIZER®, macromonomer (30 gm) was added and the contents were stirred for 10 minutes with a magnetic stirrer. The mixture was next introduced to the MICROFLUIDIZER® and cycled at least 25 times at 14,000 psi/96,527 kPa. The particle size was determined to be 288 nm. At this point, AIBN (0.22 gm) was added and the emulsion was transferred to a 3-neck flask fitted with a nitrogen inlet and condenser and the heating was continued. After 24 hours, more AIBN (0.1 gm) was added. The heating was stopped after 28 more hours of heating. The total heating time was 68 hours. A portion of the emulsion (9 gm) was removed and the rest of the emulsion was broken by pouring it into methanol (405 gm) and a solution of NaCl in water (5 gm in 25 ml). The mixture was shaken vigorously. An off-white, sticky, polymer was obtained on the surface, which was dried under vacuum. The yield was 24.4 gm.

Example 2 was similar to Example 1, except that additional amounts of AIBN were added during the reaction. The polymerization was continued for 68 hours. After breaking the emulsion, the polymer was analyzed by GPC. The Mn, Mw and Mw/Mn values in toluene and chloroform are listed in Table 1.

Example 3

Deionized water (150 gm) was placed in 250 ml beaker equipped with a magnetic stirrer. Sodium lauryl sulfate (0.2 gm) and cetyl alcohol (0.8 gm) were added to the water and the contents were heated to 65-67°C. for 2 hours. The contents were allowed to cool to 30-35°C. and a white gel was obtained. The gel was introduced to the MICROFLUIDIZER® and the contents were circulated at least 5 times at 10,000 psi/68,948 kPa. The contents of the MICROFLUIDIZER® were removed, the macromonomer (50 gm) was added and the mixture was stirred for 30 minutes with a magnetic stirrer. At this point, AIBN (0.45 gm) was added. The mixture was next introduced to the MICROFLUIDIZER® and cycled at least 10 times at 14,000 psi/96,527 kPa. The average particle size was determined to be 292 nm. The emulsion was transferred to a 3-neck flask fitted with a nitrogen inlet, condenser and thermometer. Nitrogen was bubbled through the solution. The emulsion was heated at 65°C. for 68 hours. A portion of the emulsion (5 gm) was removed. The particle size at this stage was determined to be 195 nm. The rest of the emulsion was broken by pouring it into methanol (400 gm) and a solution of NaCl in water (5 gm in 25 ml). The mixture was shaken vigorously and a thick, oily precipitate appeared at the top. The oil was dissolved in toluene (100 gm) and dried over anhydrous MgSO_4 . It was filtered and the solvent was removed on a rotary evaporator at 70°C. and 0.1 mm Hg. (0.13 kPa). A highly viscous, off-white oil was obtained. The yield was 44 gm.

Example 3 was similar to Examples 1 and 2, except that in Example 3, AIBN was added to the macromonomer before it was passed through the MICROFLUIDIZER®. The polymerization was continued for 68 hours. After breaking the emulsion, the polymer was analyzed by GPC. The Mn, Mw and Mw/Mn values in toluene and chloroform are listed in Table 1.

The GPC for Example 3 showed a bimodal peak for the reaction product. The Mn and weight average molecular weight (Mw) values for the high molecular weight peak were 606,600 and 788,500, respectively, whereas the Mn and Mw values for the low molecular weight peak were closer to the values observed in Examples 1 and 2. The IR spectrum of this mixture again did not show any absorption at $\sim 1640\text{ cm}^{-1}$. Example 3 clearly shows that methacryloxypropyl polydimethylsiloxane macromonomer is conveniently homopolymerized in high yield by our method.

As noted above, the characteristics of the macromonomer and the polymer products of Examples 1-3 are shown in Tables 1 and 2.

TABLE 1

Emulsion Polymerization of Macromonomer (MM)				
Example	% Conversion of MM	GPC in Toluene (RI)		
		Mn	Mw	Mw/Mn
1	71	104,300	186,700	1.79
2	82	116,100	198,900	1.71
3	72	144,000	400,000	2.78
		606,600	788,500	1.3
Macromonomer (MM)		11,330	12,330	1.08

TABLE 1 - Continued

Example	% Conversion of MM	GPC in CHCl ₃ (IR)		
		Mn	Mw	Mw/Mn
1	71	70,960	152,100	2.14
2	82	82,210	168,700	2.05
3	72	121,200	581,600	4.79
		1,114,000	1,401,000	1.25
Macromonomer (MM)		5,290	5,910	1.11

Regarding Table 1, it is noted that the molecular weight distribution of a polymer sample describes the relative numbers of molecules of all molecular weight values. Averages of molecular weight, such as the number-average molecular weight M_n and the weight-average molecular weight M_w , are parameters commonly used to describe the general shape of the molecular weight distribution. One convenient measure of the molecular weight distribution of a polymer is the ratio of weight-average molecular weight M_w to number-average molecular weight M_n , (M_w/M_n) or polydispersity of the polymer. For a perfectly uniform monodisperse polymer, this ratio is one.

TABLE 2

Surface Tension and Viscosity Data for Methacryloxypropyl Dimethylsiloxane and Homopolymerization Products Thereof		
Sample	Surface Tension (dynes/cm)	Viscosity (cP/mPa · s)
Macromonomer	20.8	25 ± 10
Example 1	20.3	1510 ± 40
Example 2	22.3	2030 ± 50
Example 3	22.5	12970 ± 100

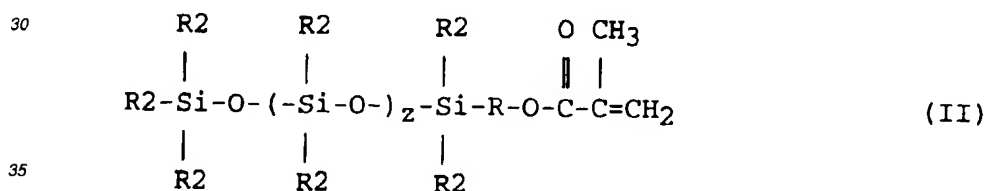
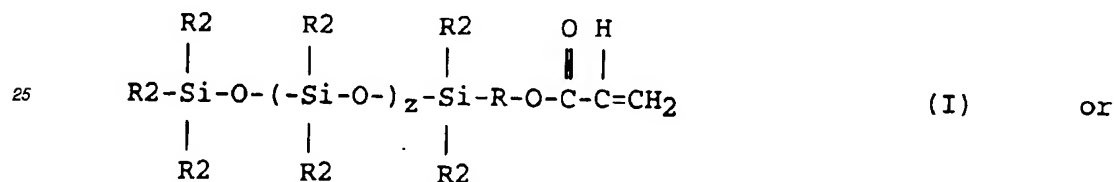
The thermal stability of the polymeric blend, i.e., the reaction product and the functional and nonfunctional unreacted macromonomer, obtained in Examples 2 and 3, was also compared by thermogravimetric analysis. Both showed 38% weight loss at 500°C. After that, the blend from Example 2 showed a sharp weight loss, i.e., 85% at 550°C.; almost a complete loss at 570°C.; and a complete weight loss at 700°C. No significant difference in thermal stability of the two blends was observed, however.

The preparation of homopolymers of polydiorganosiloxanes having acryloxy or methacryloxy groups in emulsion form provides many advantages and benefits. For example, since acryloxy and methacryloxy functional polyorganosiloxanes cannot generally be homopolymerized in solution, the miniemulsion polymerization process claimed herein provides a technique where monomers are readily polymerized to high molecular weight polymers and yet the emulsions are very stable. The resulting water-based emulsions provide low content of volatile organic compound (VOC) and allow for ease of handling of the polyorganosiloxane polymers.

These highly viscous homopolymers have applications in the personal care arena, i.e. as cosmetics; and in the ink, paint and coating industries. They can also be used as additives in lubricants for the auto and oil industry. Typically, these emulsions are used without first extracting the homopolymer; and this is convenient since most silicones are delivered in emulsion form in such industries and especially in personal care. The result is a significant savings in cost of production.

Claims

1. A method of making an emulsion containing a homopolymer of a polyorganosiloxane having acryloxy or methacryloxy groups, comprising heating and shearing a reaction mixture formed by combining (i) water; (ii) an anionic surfactant, a cationic surfactant, a nonionic surfactant, or a combination thereof; (iii) a cosurfactant which is a hydrophobic solvent, or a compound selected from the group consisting of fatty alcohols, n-alkanes and halogen substituted n-alkanes; (iv) a mono-acryloxyalkyl terminated polydiorganosiloxane macromonomer (I) or a mono-methacryloxyalkyl terminated polydiorganosiloxane macromonomer (II) having the formula



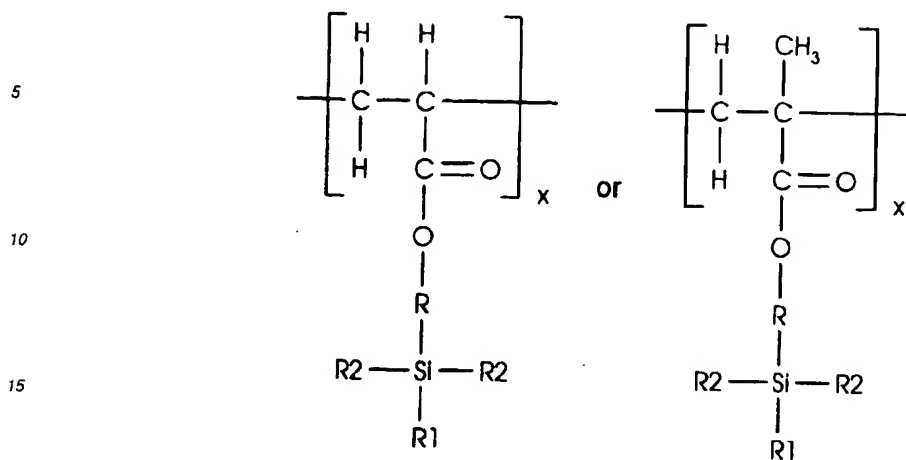
where R in each formula is a divalent hydrocarbon radical with 1-6 carbon atoms; R² in each formula is a hydrogen atom, a C₁₋₈ alkyl radical, a haloalkyl radical, or an aryl radical; and z in each formula is 1-1,000; and (v) a free radical initiator.

2. A method according to claim 1 in which the cosurfactant is a compound selected from the group consisting of cetyl alcohol, n-hexadecane and 1-chlorodecane.
3. A method according to claim 2 in which the free radical azo initiator is a compound having the formula



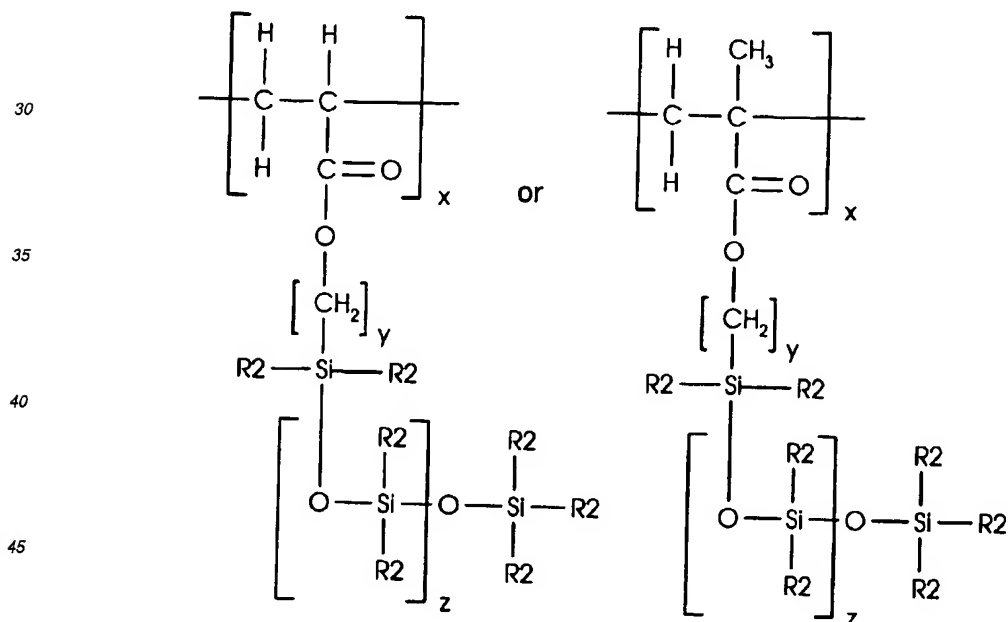
where R' is an alkyl radical and Q is a carboxylic acid residue.

4. A method according to claim 1 in which the homopolymer of the polyorganosiloxane having acryloxy or methacryloxy groups has the formula



20 where R₁ in each formula is the polydiorganosiloxane moiety $-(\text{OSiR}_2)_z\text{OSiR}_2$; R₂ in each formula is a hydrogen atom, a C₁₋₈ alkyl radical, a haloalkyl radical or an aryl radical; R in each formula is a divalent hydrocarbon radical with 1-6 carbon atoms; x in each formula is 2-5000 and z in each formula is 1-1,000.

25 5. A method according to claim 4 in which the homopolymer has the formula



50 where R₂ in each formula is the hydrogen atom, a C₁₋₈ alkyl radical, a haloalkyl radical or an aryl radical; x in each formula is 2-5000; y in each formula is 1-6; and z in each formula is 1-1,000.

6. An emulsion obtainable by the method according to any of claims 1-5.

55 7. A method of preparing a homopolymer of a polyorganosiloxane having acryloxy or methacryloxy groups by isolating the copolymer from the emulsion of claim 6.

8. Homopolymer obtainable by the process of claim 7.



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EUROPEAN SEARCH REPORT

Application Number
EP 97 12 2761

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	EP 0 378 370 A (ROHM & HAAS) * page 3, line 30-37 * * page 6, line 19-47 * * page 7, line 34 - page 8, line 58 * * page 9, line 37 - page 10, line 11; claim 4; examples * ---	1-8	C08F283/12 C08J3/16 C08F2/24 C08G77/442 C08L83/14
A	EP 0 632 157 A (SHINETSU CHEMICAL CO ;KONISHI CO LTD (JP)) * the whole document * ---	1-8	
A,D	P.L.TANG, E.D. SUDOL, C.A. SILEBI AND M.S.EL-AASSER: "Miniemulsion Polymerization - A Comparative Study of Preparative Variables" JOURNAL OF APPLIED POLYMER SCIENCE, vol. 43, 1991, page 1059-1066 XP002060144 * the whole document * -----	1-8	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			C08F C08J C08G C08L
The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 25 March 1998	Examiner Hutton, D
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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